Presents...

Grounding for Power Quality
P3 is the industry’s trusted and respected advisor for critical power, cooling and energy solutions.
DATA CENTERS

Providing industry knowledge, product expertise, & technological innovation over a broad portfolio of products and services to our customers across a wide range of industries and applications.

To achieve zero downtime, scale the data center to meet ever changing requirements, and reduce energy costs, you need the most reliable and efficient power and cooling infrastructure available.

Modular & Scalable Data Center Equipment
Systems that grow and change with your modern Data Center.

Traditional Data Center Equipment
Systems built around existing older equipment.

We can provide both
Modular / Scalable and Traditional Data Center Equipment
INDUSTRIAL
POWER SOLUTIONS

Power Quality Specialists with expertise in your Power Quality needs.

Industrial Power Quality, doesn’t just happen. It takes technical expertise, investment in products and facility coordination to achieve the desired levels of Power Quality. With experience in both new construction and retrofit installations, P3 can help you select and install the correct products.
Power Quality Monitoring

System analysis and evaluation of power quality issues to provide solution recommendations for the best possible performance from your existing power system.

The ability to quickly identify and remedy power quality problems will lengthen the life of electrical equipment and improve power system availability.

Our engineering technicians will help you understand your unique facility power system.
Service Plans & Support Services

Service plans and support services that provide maintenance, parts, & service necessary to ensure the best possible performance from your existing power system.

We offer customized, flexible, full-service packages that offer hassle-free system maintenance to improve uptime at predictable cost which include technical support, preventive maintenance, quick on-site response, and remote monitoring:

- Service Plans
- Energy Management Services
- Power & Cooling Analysis
- Data Center Assessments
- Project Management
- Battery Replacement

We provide top quality maintenance service & support
NEC 250.53 states that ground resistance should be less than 25 ohms.

Is this true?
No!

NEC 250.53 states “A single... electrode shall be supplemented by an additional electrode... If a single... electrode has a resistance to earth of 25 ohms or less the supplemental electrode shall not be required”.

Is this good enough?
(B) Adequacy. This Code contains provisions that are considered necessary for safety. Compliance therewith and proper maintenance results in an installation that is essentially free from hazard but not necessarily efficient, convenient, or adequate for good service or future expansion of electrical use.

(A) Practical Safeguarding. The purpose of this Code is the practical safeguarding of persons and property from hazards arising from the use of electricity. This Code is not intended as a design specification or an instruction manual for untrained persons.

NFPA 70
National Electrical Code®
2014 Edition

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This 2014 edition includes the following usability features as aids to the user. Changes other than editorial are highlighted with gray shading within sections and with vertical ruling for large blocks of changed or new text and for new tables and changed or new figures. Where one or more complete paragraphs have been deleted, the deletion is indicated by a bullet (•) between the paragraphs that remain. The index now has dictionary-style headers with helpful identifications at the top of every index page.

ARTICLE 90
Introduction

90.1 Purpose

(A) Practical Safeguarding. The purpose of this Code is the practical safeguarding of persons and property from hazards arising from the use of electricity. This Code is not intended as a design specification or an instruction manual for untrained persons.

(B) Adequacy. This Code contains provisions that are considered necessary for safety. Compliance therewith and proper maintenance results in an installation that is essentially free from hazard but not necessarily efficient, convenient, or adequate for good service or future expansion of electrical use.

Informational Note: Hazards often occur because of overload of wiring systems by methods or usage not in conformity with this Code. This occurs because initial wiring did not provide for increases in the use of electricity. An initial adequate installation and reasonable provisions for system changes provide for future increases in the use of electricity.

(C) Relation to Other International Standards. The requirements in this Code address the fundamental principles of protection for safety contained in Section 131 of International Electrotechnical Commission Standard 60364-1, Electrical Installations of Buildings.

Informational Note: IEC 60364-1, Section 131, contains fundamental principles of protection for safety that encompass protection against electric shock, protection against thermal effects, protection against overcurrent, protection against fault currents, and protection against overvoltage. All of these potential hazards are addressed by the requirements in this Code.

90.2 Scope

(A) Covered. This Code covers the installation of electrical conductors, equipment, and raceways; signaling and communications conductors, equipment, and raceways; and optical fiber cables and raceways for the following:

1. Buildings, structures, mobile homes, recreational vehicles, and floating buildings
2. Yards, lots, parking lots, and industrial substations
3. Installations of conductors and equipment that connect to the supply of electricity
4. Installations used by the electric utility, such as office buildings, warehouses, garages, machine shops, and recreational buildings that are part of a generating plant, substation, or control center.

(B) Not Covered. This Code does not cover the following:

1. Installations in ships, watercraft other than floating buildings, railway rolling stock, aircraft, or nonmobile vehicles other than mobile homes and recreational vehicles

Informational Note: Although the scope of this Code indicates that the Code does not cover installations in ships, portions of this Code are incorporated by reference into Title 46, Code of Federal Regulations, Parts 105–113.

2. Installations underground in mains and self-propelled mobile surface mining machinery and its attendant electrical trailing cable

3. Installations of railways for generation, transformation, transmission, or distribution of power used exclusively for operation of rolling stock or installations used exclusively for signaling and communications purposes

4. Installations of communications equipment under the exclusive control of communications utilities located outdoors or in building spaces used exclusively for such installations

5. Installations under the exclusive control of an electric utility where such installations a. Consist of service drops or service laterals, and associated metering, or b. Are on property owned or leased by the electric utility for the purpose of communications, metering, generation, control, transformation, transmission, or distribution of electric energy, or
IEEE Recommended Practice for Powering and Grounding Electronic Equipment

Sponsor
Power Systems Engineering Committee
of the
Industrial and Commercial Power Systems Department
of the
IEEE Industry Applications Society

Abstract: Recommended design, installation, and maintenance practices for electrical power and grounding (including both power-related and signal-related noise) of sensitive electronic processing equipment used in commercial and industrial applications are presented. The main objective is to provide a consensus of recommended practices in an area where conflicting information and confusion, stemming primarily from different viewpoints of the same problem, have occurred. Practical herein address electronic equipment performance issues while maintaining a safe installation. A brief overview is given of the nature of power quality problems, practical solutions, and the resources available for assistance in dealing with problems. Fundamental concepts are reviewed, instrumentation and procedures for conducting a survey of the power distribution system are described, site surveys and site power analysis are considered. Case histories are given to illustrate typical problems.

Keywords: commercial applications, electronic power, grounding, industrial applications, sensitive equipment.
Why do we ground our electrical systems?

We ground our electrical systems for two reasons:

1. For Safety
2. For Power Quality

This seminar will discuss safety, however, our primary topic is POWER QUALITY.
The Power Quality Pyramid

- Custom Solution
- Uninterruptible Power Supply System
- Power Conditioning
- Harmonic Cancellation
- Grounding and Surge Protection Devices
The basic “Safety” grounding system

(Normal Conditions)

Transformer 480V Secondary

Panel

20Amp CB

Motor/Load (40 Ohms)

Equivalent Circuit

480 Volts

40 Ohms

? Amps

12
The basic "Safety" grounding system

(Ground Fault condition)

Transformer 480V Secondary

Panel

20Amp CB

N

G

Breaker Trips

Motor/Load

Internal Ground Fault .2 Ohms

Equivalent Circuit

480 Volts .2 Ohms

2400

V

A

R

Building Confidence in Power
The basic “Safety” grounding system

Equivalent Circuit

480 Volts

40 Ohms

.2 Ohms

20Amp CB

Panel

Transformer 480V Secondary

Motor/Load

Internal Ground Fault

.2 Ohms

Breaker Does NOT Trip

(No/poor ground)

12

Building Confidence in Power
The basic “Safety” grounding system

(No/poor ground w/people)

Transformer 480V Secondary

Panel

20Amp CB

N

G

Motor/Load

Internal Ground Fault

.2 Ohms

Breaker Does NOT Trip

20,000 Ohms

Equivalent Circuit

480 Volts

40 Ohms

20,000 Ohms

24mA Can Kill!

20,000 Ohms

? Amps
The grounding of sensitive electronic equipment, such as computers, programmable logic controllers, process plants, distributed control systems, and similar electronic equipment, has been found to be one of the important items in achieving useful operation from these systems.

The low operating voltage of computers and other sensitive electronic equipment makes them susceptible to random voltages far below levels that are perceptible to humans and that have no effect on electrical power equipment.

Certainly the voltages injected into the earth by lightning strokes even within several thousand feet, unless suitable neutralization is accomplished, can cause malfunction and can possibly damage the equipment.
UnGrounded system
An electrical system in which there is no intentional connection between the conductors and earth.

What happens if we have a fault here?
UnGrounded system
An electrical system in which there is no intentional connection between the conductors and earth.

**Advantages**
Service Continuity.

**Disadvantages**
Very High ground currents due to leakage Capacitance in the entire system.

Power System overvoltages passed into the premises wiring system.
(Lightning, switching surges, inter-contact between high voltage systems)

Transients are not controlled.
System voltages can be unbalanced.
Grounded Systems

Grounded system - Delta
An electrical system in which there is an intentional connection between the conductors and earth.

Disadvantages
- Avoidance of installing equipment ground fault protection as required by the NEC on solidly grounded Wye electrical services.
- The system is unable to supply dual-voltage service for lighting and power loads.
- It requires a positive identification of the grounded phase throughout the system.
- A higher line-to-ground voltage exists on two phases than in a neutral-grounded system.
- Fault switching (opening) is much more severe for the clearing device, and ratings may be greatly reduced.
- Many manufacturers’ electrical distribution equipment is not rated for use on this system.
- They are not recommended for new installations because more suitable and reliable systems are available today.
- Power System overvoltages passed into the premises wiring system.
- Transients are not controlled.

Advantages
- High fault currents may flow on the first ground fault, requiring the immediate clearance of this first fault.
- The voltage to ground in this system will be the system voltage, usually 240 or 480 volts.
Grounded Systems

Grounded system - Wye
An electrical system in which there is an intentional connection between the conductors and earth.

May be Resistive ground type
Grounded Systems

Grounded system - Wye
An electrical system in which there is an intentional connection between the conductors and earth.

Advantages
Low ground currents due to no leakage Capacitance in the system.
Power System overvoltages attenuated into the premises wiring system.
Transients attenuated.
System voltages balanced.
Personnel Safety.

Disadvantages
Some may argue for Service Continuity, however, many more power quality problems usually occur with ungrounded systems.
IEEE 142 (4.1.2) states that ground resistance should be 1 ohm for substations and 1-5 ohms for commercial and industrial services. Many equipment vendors require less than 3 ohms.

Why?
IEEE States:

A quality connection to earth through the grounding electrode system for a commercial or industrial facility's power system is necessary for:

- Providing a low impedance path for lightning stroke current dissipation
- The reduction of “Step” and “Touch” potentials under line-to-earth fault conditions
- The dissipation of electrostatic charges
- The proper operation of electrical and electronic equipment
- The proper operation of Surge Protection Devices (SPD’s) (TVSS units)
IEEE 142-4.1.2 Recommended Acceptable Values

- The most elaborate grounding system may not perform satisfactorily unless the connection of the system to earth is adequate for the particular installation.

- The earth connection is one of the most important parts of the whole grounding system.

- The connection to earth or the electrode system, needs to have a sufficiently low resistance to help permit prompt operation of the circuit protective devices in the event of a ground fault, to provide the required safety from shock to personnel who may be in the vicinity of equipment frames, enclosures, conductors, or the electrodes themselves and to limit transient overvoltages.
How many rods do you need?

Using information from two sources lets look at a typical ground rod installation.

Source #1- ANSI/IEEE 142

Source #2- White Paper - DEEP EARTH GROUNDING VERSUS SHALLOW EARTH GROUNDING by Martin D. Conroy and Paul G. Richard
Does this meet IEEE standards?

Using IEEE 142 4.1.4

Service Entrance Panel

1-10’ ground rod 25 ohms to earth
2-10’ ground rods 15 ohms to earth
3-10’ ground rods 11 ohms to earth

Using Deep Earth paper

Service Entrance Panel

1-10’ ground rod 25 ohms to earth
1-20’ ground rod 7 ohms to earth
1-30’ ground rod 4 ohms to earth
Soil Moisture Changes

NEC 250.53 states ....that ground electrodes shall be embedded below permanent moisture level.
Soil Moisture Changes

Soil moisture content varies greatly down to about 10 feet.

Does not peak dry much below 30 feet.
Soil Moisture Changes

Calculated Soil Moisture Anomaly (mm)

MAY, 2013

Calculated Soil Moisture Anomaly (mm)

JUL, 2013

Calculated Soil Moisture Anomaly (mm)

JUN, 2013

Calculated Soil Moisture Anomaly (mm)

OCT, 2013
Soil Moisture Changes

Calculated Soil Moisture Anomaly
Soil Moisture Changes

Calculated Soil Moisture Anomaly

Calculated Soil Moisture Anomaly (mm)
SEP, 2017

[Map showing soil moisture changes across the United States with color-coded anomalies]

Building Confidence in Power
IEEE 142-4.4.1 Need for Measurement
Many indeterminate factors exist in any formula for the calculation of the resistance to earth. Total reliance should not be placed on the calculated results. For example, the soil resistivity varies inversely with the soil temperature and directly with the moisture content and may vary with the depth. The only certain way to determine the resistance is to measure it after the system has been completed.

IEEE 142-4.4.3 Periodic Testing
Tests should be made periodically after the original installation and test so that it can be determined whether the resistance is remaining constant or is increasing. If later tests show that the resistance is increasing to an undesirable value, steps should be taken to reduce the resistance…

Don’t bury it and forget it!
Two Main Methods:
1. Fall of Potential Method
2. Signal Injection Method
Fall of Potential Method

- Service Entrance Panel
- Ground Meter
- Ground Electrode

Must be Disconnected!

Area of Influence
Fall of Potential Method
Signal Injection Method

Service Entrance Panel

Ground Electrode

Must be Connected!

Area of Influence

Meter
IEEE 142 5.5.3 Insulated Grounding Conductors

- Reliance on the metal raceway is not recommended.
- An internal grounding conductor improves the efficiency of the ground return path.
- Internal ground-return conductors do improve reliability, especially when sensitive electronic equipment grounding is a concern.
Best Practice

Ground system

Insulated ground conductor sized by code (Bigger is better)

Centralized ground bar
In facility

Handhole box

10’

30’ Minimum (less than 5 ohms)
Don’t install it and forget it!
IEEE 142 5.5.4.3 Problems

Analysis… (indicates) that the separation of grounds was responsible for very large voltages being impressed on computer components under thunderstorm conditions. **These voltages occurred whether or not computers were in operation.** The large voltages were due to lightning striking either the building housing the computers or the power system serving the building. When charge centers on lightning clouds were overhead, charges were induced in buildings on the ground beneath them.

For Example
Is this correct?
Grounding for Power Quality

Service Entrance

Sensitive Equipment

Ground Rod #1

10 Ohms

Ground Rod #2
Grounding for Power Quality

Service Entrance

Sensitive Equipment

Ground Rod #1

10 Ohms

Ground Rod #2

Ground current of 1000Amps caused by lightning
Ohms x Amps = Volts

10 Ohms x 1000Amps = 10,000Volts

Ground current of 1000Amps caused by lightning
Ohms x Amps = Volts

10 Ohms x 1000Amps = 10,000Volts

Ground current of 1000Amps caused by lightning

Sensitive Equipment

Service Entrance

10,000Volts between ground rods

10 Ohms

Ground Rod #1

Ground Rod #2

Building Confidence in Power
Solution

Service Entrance

Sensitive Equipment

Bond ground rods

Ground Rod #1

Ground Rod #2
IEEE 142 1.6.6

Connection of the equipment ground to earth with an electrode that is physically separate from all other power system and structural grounding electrodes and is not bonded to any of these other grounding electrodes, will inevitably produce common mode noise, since it is not referenced to the power source ground. The magnitude of this common mode potential can be destructive to the equipment and hazardous to personnel, since a power system fault can raise the power system or structure several hundred or thousand volts above other earth references. This grounding method is also in direct violation of the NEC-NFPA 70, Article 250.30.
Ground Loops

Ungrounded Conductor
Current Flow (Hot)

Grounded Conductor
Current Flow (Neutral)

None
Ground Loops

Current Flow

Return neutral current flowing on Ground

Bad

Computers
VFD’s
PLC’s
Sensitive Equipment

Main Panel

Sub Panel
Current Flow

Return neutral current flowing on Ground

Worse

Stray neutral current flowing through sensitive equipment

Building Confidence in Power

www.p3-inc.com
Ground Loops

Current Flow

Return neutral current flowing on Ground

Computers
VFD’s
PLC’s
Sensitive
Equipment

Main
Panel

Sub Panel

Stray neutral current flowing through sensitive equipment via
Phone & data cable

Worst

Stray neutral current flowing through sensitive equipment
Dedicated Circuits

Sensitive Equipment

Other Equipment

Worst
Isolation Transformer Circuit

Harmonic Cancellation
Isolation Transformer or
Low Harmonic UPS System

Better

Panel

Sensitive Equipment

Other Equipment

Must Be Bonded
Separate Circuits

Building Confidence in Power
Isolated Ground Circuits
Isolated Ground Circuits

IEEE 1100

• 3.3.4- **Isolated ground systems are likely to exaggerate power line surges** *because they do not equalize voltages between different system feeders.*

• 3.3.5.1- **Isolated grounding may cause stray currents and voltages due to transients.**

• 4.4.5.1- **Isolated grounding systems rarely (if ever) provide the anticipated protection from EMI (electrical noise) on the… system. This is due to the fact that almost all internal circuits in electronic equipment are grounded to the frame of that equipment.**
The Grounding System

An effective grounding system:

• Using SPD units provides a more stable system with a minimum of transient voltages and electrical noise.

• Provides a path to ground in fault conditions to insure proper operation of ground fault protection equipment.

• Provides grounding of all conductive enclosures that may be touched by personnel, thereby eliminating shock hazards.
An effective grounding system:

• Reduces static electricity that may be generated within facilities.

• Provides protection from large electrical disturbances (such as lighting) by creating a low resistive path to earth.

• Eliminates ground loops that induce voltages into sensitive equipment.
The Power Quality Pyramid

- Custom Solution
- Uninterruptible Power Supply System
- Power Conditioning
- Harmonic Cancellation
- Grounding and Surge Protection Devices
END

Please fill out the evaluation form to receive attendance credit.

An Email Address **MUST** be Provided to receive your attendance certificate.

Thank you for attending PQU’s Grounding for Power Quality